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THE USE OF COVER CROPS TO CONTROL TREE INVASION ON A RIGHT-OF-WAY NEAR TOBERMORY III. CROP ESTABLISHMENT AND TREE INVASION FOLLOWING THE SECOND GROWING SEASON

Report No 91-2-K
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ABSTRACT

The effectiveness of red fescue (*Festuca rubra*), orchard grass (*Dactylis glomerata*), birdsfoot trefoil (*Lotus corniculatus*) and crown vetch (*Coronilla varia*) in the control of incompatible trees is under investigation on a distribution line near Tobermory. The results following the second growing season have indicated an improvement in the establishment of these species, with cover and frequency highest for red fescue and orchard grass, and lowest for birdsfoot trefoil. None of the treatments have affected the density of incompatible trees on the right-of-way.

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34-541-031	634.1	February 20, 1991	91-2-K

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EXECUTIVE SUMMARY

THE USE OF COVER CROPS TO CONTROL TREE INVASION ON A RIGHT-OF-WAY NEAR TOBERMORY III. CROP ESTABLISHMENT AND TREE INVASION FOLLOWING THE SECOND GROWING SEASON

D. Brown

In the past two decades Ontario Hydro has relied on selective herbicide applications to remove incompatible trees from its transmission and distribution rights-of-way. This approach was designed to encourage a type of biological control, where the compatible groundcover slows the invasion of tree species via competitive or allelopathic interactions. The success of this technique is dependent upon the occurrence of species in the area which are able to successfully interfere with tree establishment and/or growth. If such species are not present, or are unable to establish on the right-of-way, no effective biological control can develop.

An alternative method of establishing this control is by replacing the existing vegetation with species that have a demonstrated ability to interfere with tree establishment. Cover crops have been used by Ontario Hydro for a number of years for erosion and weed control, but few studies have been undertaken to determine their potential role in a biological control strategy.

A distribution line in the Tobermory area of the Bruce Peninsula became available for an experimental cover crop planting. The line was cleared of incompatible species during the fall and winter of 1988. A random block experimental design was used to test 6 treatments at 6 sites along this right-of-way. The treatments consisted of a) soil scarification and seeding with creeping red fescue (*Festuca rubra*), b) soil scarification and seeding with juno orchard grass (*Dactylis glomerata*), c) soil scarification and seeding with birdsfoot trefoil (*Lotus corniculatus*), d) soil scarification and seeding with a mixture of penngift crown vetch (*Coronilla varia*) and perennial ryegrass (*Lolium multiflorum*), e) soil scarification with no seeding and f) no soil scarification and no seeding.

The cover crops did not develop an extensive cover in any of the seeded plots during the first year, probably due to drought conditions. They were reseeded in the second year. At the end of the 1990 growing season, the crops were established in their respective plots with good frequencies (ranging from 20 to 100%). Red fescue and orchard grass had a mean cover of 25% and could be considered as the dominant ground cover in their treatment plots. Crown vetch and birdsfoot trefoil had relatively low covers of 5 and 2%.

Incompatible trees were found at the study area, with densities varying at each site. Densities were not statistically affected by the treatment, but had not increased from last year.

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THE USE OF COVER CROPS TO CONTROL TREE INVASION ON A RIGHT-OF-WAY NEAR TOBERMORY III. CROP ESTABLISHMENT AND TREE INVASION FOLLOWING THE SECOND GROWING SEASON

1.0 INTRODUCTION

Cover crops have been used on utility rights-of-way for erosion and weed control. There is, however, an increasing need to broaden the scope of cover crop usage to include them as a vital part of an integrated vegetation management program. Such a program requires the harmonic blending of the biological control exerted by cover crops or stable natural vegetation communities with tree removal via herbicides, mechanical or manual cutting.

Unfortunately, there is a considerable lack of information on the ability of a cover crop to control incompatible vegetation. Studies on Georgia, Tennessee, Alabama and Maryland rights-of-way suggested that this technique may reduce tree densities or maintenance costs (Arner 1960, 1966; Leith 1974). In Ontario, Gillespie (1978) suggested that a cover cropped right-of-way would reduce maintenance time by 25%, while Suffling (1979) stated that cover crop mixtures "appear to be generally more effective in brush control than either blanket foliage sprays or selective cutting." Unfortunately, no firm conclusions can be drawn from their results of these studies since they were either poorly designed or entirely anecdotal in nature.

A comprehensive review of the literature concerning the management of incompatible trees with cover crops underlines the general lack of information on this topic (Brown 1989a). The orchard and forestry industries have identified situation-specific cases where some cover crops were more inhibitory to tree growth than natural vegetation communities. However, there was an insufficient number of studies from areas with a climate comparable to Ontario's to specify any particular crop species for immediate use (Brown 1989a).

This project has been initiated to evaluate the suitability of four cover crop species for incompatible tree control on a distribution line near Tobermory. The first year results (Brown 1990a) indicated that crop establishment was poor, and there was no improvement in the control of incompatible species. This report discusses results of the second year of this study.

2.0 METHODS

2.1 Experimental Design

The experiment was arranged in a random block design using 6 treatments at 6 sites (blocks) on the Eagle Harbour to Pendal-Point distribution line, with no within-site replication. A preliminary survey of the sites was conducted in 1988 (Brown 1989b). Of the 10 sites included in this survey, only 6 were chosen for the project. Sites A to F correspond to sites 1 to 5 and 9 of the 1988 survey.

The treatments consisted of: soil scarification and seeding with creeping red fescue (*Festuca rubra*) (RF); soil scarification and seeding with juno orchard grass (*Dactylis glomerata*) (OG); soil scarification and seeding with birdsfoot trefoil (*Lotus corniculatus*) (BT); soil scarification and seeding with a mixture of penngift crown vetch (*Coronilla varia*) and perennial ryegrass (*Lolium multiflorum*) (CV); soil scarification with no seeding (scarified control) (SCo); no soil scarification and no seeding (control) (Co). The plots were 30 m long by the width of the right-of way, which varied from 2 to 6 m.

The sites were scarified and planted in May, 1989. Orchard grass and red fescue were seeded at a rate of 2 kg/plot, birdsfoot trefoil at 0.88 kg/plot, and the 50% crown vetch - 50% rye mixture at 1.76 kg/plot. These seeding rates were 2 to 3 times higher than those recommended by the seed supplier (F.R. Smith Seeds Ltd, Toronto). Due to poor establishment in 1989, the plots were reseeded (without scarification) on June 3, 1990. The orchard grass, red fescue and birdsfoot trefoil plots were reseeded at the rate mentioned above, while the crown vetch plots were reseeded with 100% crown vetch at a rate of 0.88 kg/plot.

2.2 Data Collection

The vegetation in each plot was assessed between August 13 - 30, 1990, using the Domin scale (described in Table 1) to subjectively estimate cover in 0.5 x 0.5 m quadrats (Brown 1989b). The quadrats were placed at 5 m intervals along three transects running the length of each plot. One transect was located in the middle, while the other two were situated 0.5 m from each edge of the plot. A total of 15 quadrats (5 per transect) were measured in each plot, encompassing 1-3% of the plot area. In addition to this, all trees found within each plot were categorized in 0.5 m height classes. A list of species found in the quadrats in the 1990 survey is included in the appendix.

Table 1

The Domin Scale of plant abundance and cover

Abundance	Domin Rating	Currall (1987) Transformation
Cover about 100%	10	99.5
Cover above 75%	9	75.7
Cover of 50 to 75%	8	55.7
Cover of 33 to 50%	7	39.4
Cover of 25 to 33%	6	26.4
Abundant, cover of 20 to 25%	5	16.4
Abundant, cover of 5 to 20%	4	9.2
Scattered with small cover	3	4.3
Very scattered with small cover	2	1.5
Scarce, small cover	1	0.3

2.3 Data Analysis

2.3.1 Quadrat Classification

A classification is based on the premise that recurring units of vegetation exist, and the differences within these natural groupings is unimportant when compared to the differences between classes. This was used to determine if there was a different vegetation type associated with the different treatments. Two-way indicator species analysis (program TWINSPAN, Hill 1979) is considered to be one of the more effective classification procedures currently available (Kershaw and Looney 1985). This is a hierarchial, divisive, polythetic method based on a correspondence analysis ordination. For each division, the algorithm performs a 1 dimensional ordination, splits this into two halves and then searches for species with a distribution that shows a preference for one half over the other. This information is then used as a weighting in a second, improved ordination, which divides the data into two new classes. This process is repeated for each resulting class until a minimum class size is reached.

After each division, a number of indictor species are selected for that division. An indicator species is one which is more than twice as likely to occur on one side of the division than on the other. They do not, however, describe the species composition of the two groups. When the groupings are finalized, the species composition may be determined from the quadrat data.

TWINSPAN is not able to use quantitative data, but uses 'pseudospecies' as dummy variables to indicate qualitative differences in abundance. Domin values of 0, 4, 6 and 8 were used to define the pseudospecies cut levels.

2.3.2 Importance Value Curves

The species composition in each plot was also depicted graphically using the importance value curves of Whittaker (1975). This curve is a plot of the importance value on the ordinant against the rank order of the species (from highest importance value to the lowest) on the abscissa. The importance value is the sum of the relative frequency and relative cover for each species in the plot. To calculate the importance value, the transformation suggested by Currall (1987) (Table 1) was used to linearize the Domin scores prior to averaging the values from the quadrats to obtain a mean cover estimate for each species in the plot. Relative cover is then calculated as:

$$\text{Relative Cover} = \frac{\text{Cover of species n}}{\text{Total cover of all species in plot}} \times 100 \qquad (1)$$

The frequency was calculated for each species in the plot by:

$$\text{Frequency} = \frac{\text{Number of quadrats with that species}}{\text{Total number of quadrats in the plot}} \times 100 \qquad (2)$$

and relative frequency was calculated according to equation (3).

$$\text{Relative Freq.} = \frac{\text{Frequency of species n}}{\text{Total frequency of all species in plot}} \times 100 \qquad (3)$$

The importance value was then calculated for each species as the sum of the relative cover and relative frequency. The species code used in the figures consists of the first 4 letters of the genus and the first 3 letters of the species name. A complete species list is provided in the appendix.

2.3.3 Statistical Analysis

Two-way analysis of variance (ANOVA) was used to investigate the different effects of treatment and site on species richness and incompatible tree density. The tree density was log transformed to normalize the data prior to analysis. A 2 x 2 contingency table analysis was used to investigate positive and negative associations between the trees and each of the more abundant species in the quadrats.

3.0 RESULTS

3.1 Cover Crop Establishment

A considerable improvement in the growth of the cover crops occurred in 1990, suggesting that poor establishment in 1989 was due to drought conditions. All the crops were present in their respective plots, with mean frequencies of 94% for red fescue, 89% for crown vetch, 81% for orchard grass and 71% for birdsfoot trefoil (Figure 1). The cover of red fescue and orchard grass had increased substantially, reaching a mean of 25%. The cover of vetch and trefoil has also increased (5 and 2%), although levels were still less adequate. It cannot be determined if this increase was due to the second seeding, or growth from those plants which were established in 1989.

The vetch and trefoil present were primarily small seedlings less that 2-3 cm in height. The high frequency provides hope that many of the seedlings will survive and flourish in subsequent years, to eventually form a good groundcover. Birdsfoot trefoil was the only species which was observed to produce seeds in 1990.

3.2 Community Analysis

Two important questions to be answered by a cover crop program are: 1) were the crops a dominant force in the plots in which they were planted?; and 2) did the vegetation communities differ between the treatments? These questions have been addressed by 3 methods: an ANOVA analysis of the species richness; the importance value curves of Whittaker(1975); a vegetation community analysis using TWINSPAN.

Species richness was expected to decline under intense competition from a dominant plant (Gurevitch and Unnasch 1989). The total number of species occurring in the quadrats ranged from 0 to 19. The means for each treatment-site combination are indicated in Figure 2, and the ANOVA table is given in Table 2. Species richness was affected significantly by both the site and the treatment. The F-ratio suggests that site effects accounts for a larger portion of variation than treatment effects. Sites E and F had the lowest species richness, while site B had the highest (Figure 2). There was, however, a significant treatment by site interaction term, which indicates that the effects of the treatments varied at each site. On average, the OG plots had the fewest species, while BT plots had the most. Scarification caused a decrease in the number of species at sites C, D and E, but an increase at site A. Seeding to any cover crop decreased the species richness (relative to SCo) at Sites A and B (except BT), but increased richness at sites D (except OG), E and F (except OG).

Figure 1: The frequency and cover of the crops seeded in their respective plots

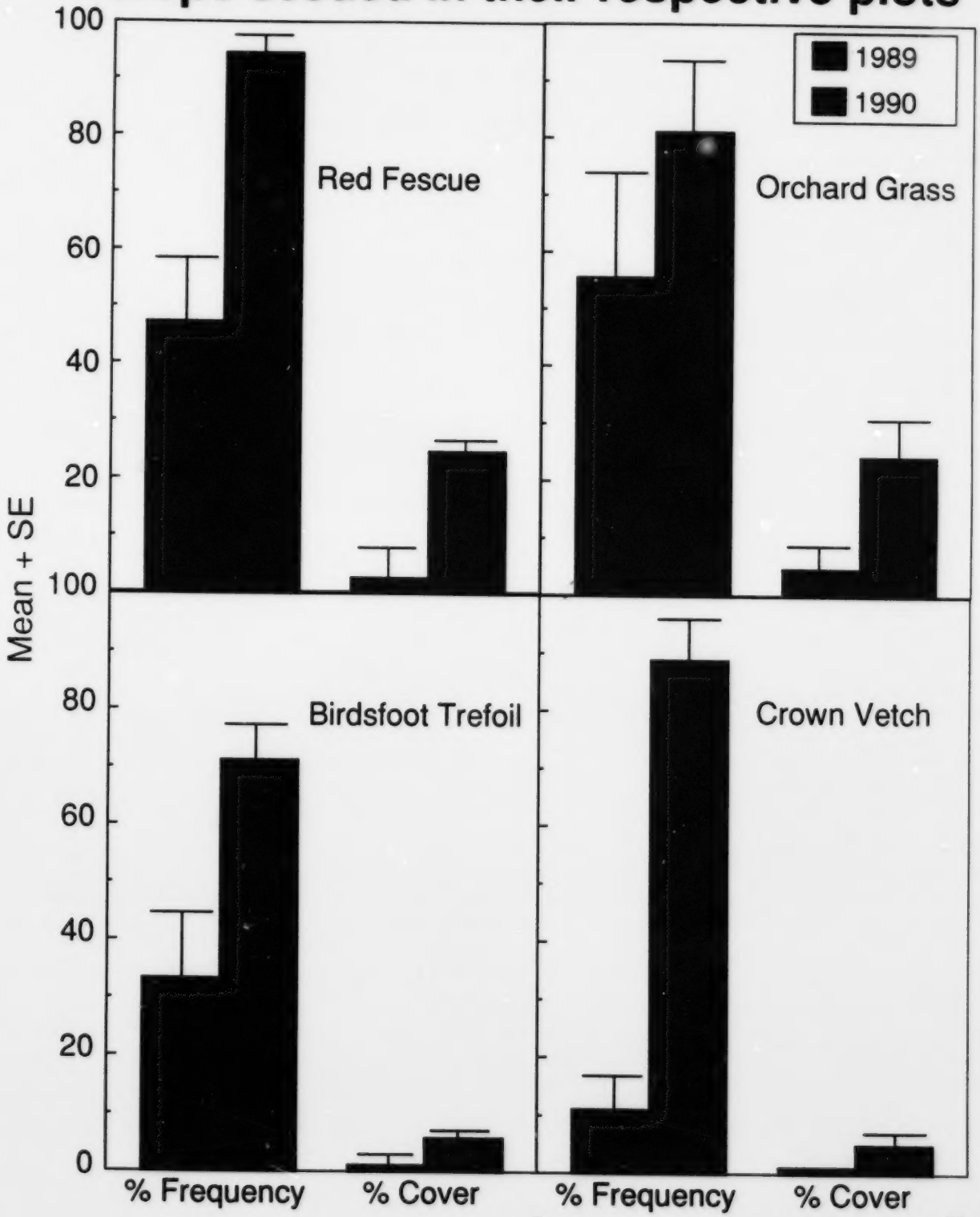


Figure 2: The effect of treatment and site on species richness

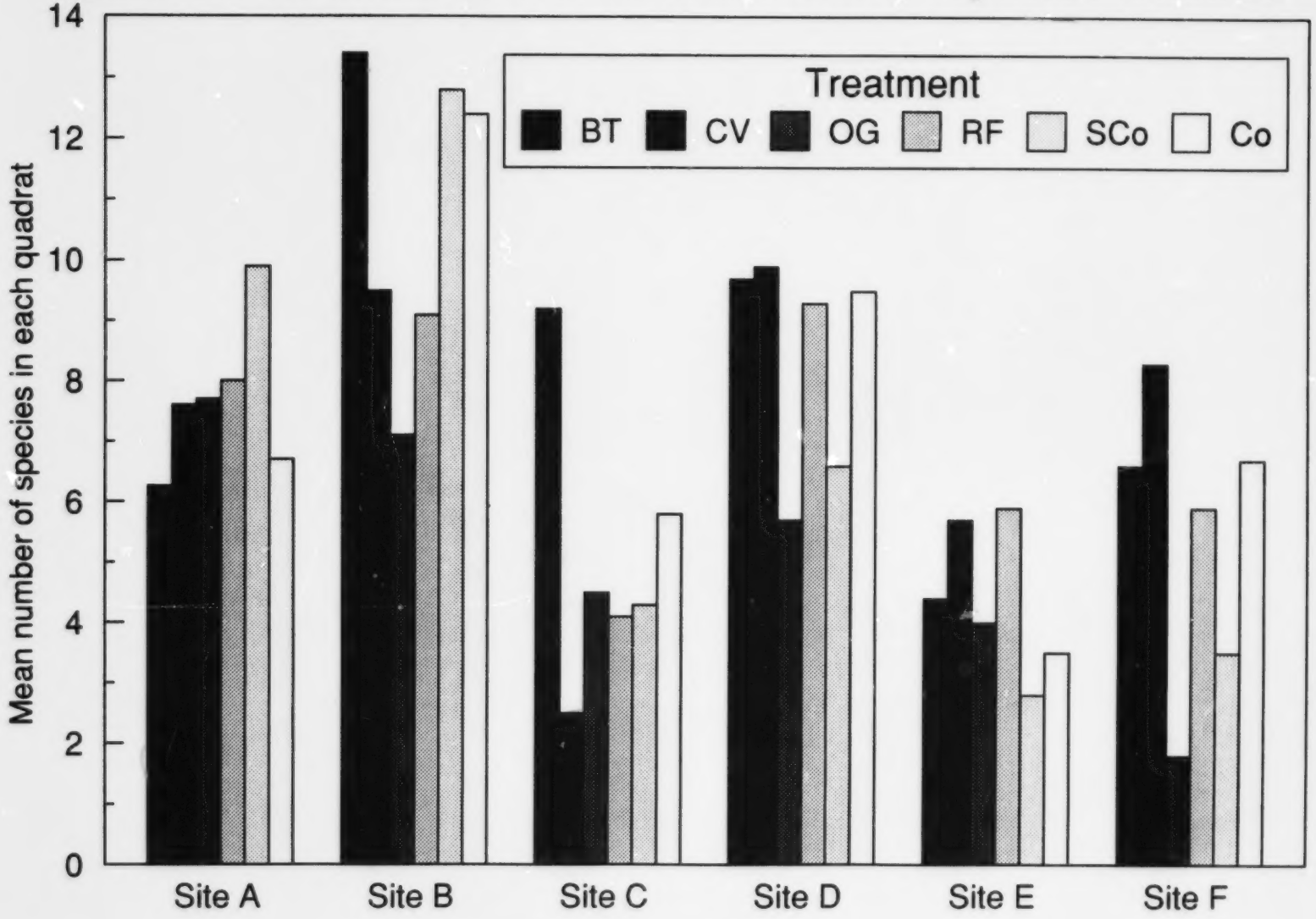


Table 2

The ANOVA of the variation in species richness between sites and cover crop treatments.

Source	SS	DF	MS	F-ratio	p
MAIN EFFECTS	3126.2111	10	312.62111	45.824	>0.00
treatment	490.8611	5	98.17222	14.390	>0.00
plot	2635.3500	5	527.07000	77.258	>0.00
INTERACTION	1289.5722	25	51.582889	7.561	>0.00
RESIDUAL	3438.4000	504	6.82222		
TOTAL (corr.)	7854.1833	539			

The ANOVA indicated some very diverse results and complex interactions. This was not surprising considering the treatments produced large differences in crop frequency and cover (Figure 1).

The importance value curves provided a method of depicting the relative influence of the cover crops in their respective plots. Birdsfoot trefoil occurred low in the importance value ranking, and does not occupy a prominent position in any BT plots (Figures 3-8). Its importance is even surpassed by red fescue in BT-E (Figure 7). Crown vetch was ranked within the top 4 species in all of the CV plots, while red fescue and orchard grass have the highest importance values of any species in their respective plots, with the exception of the orchard grass treatment in plot B, where it ranked third.

Red fescue was present in 8 of the 12 SCo and Co plots, and in 1 of the OG, 2 of the CV and 1 of the BT plots. Scattered patches of this species were observed growing in the forest openings in this area. Crown vetch and orchard grass were also found in some of the control plots (Figure 3, 4).

The TWINSPAN classification separated the quadrats into 8 groups after 6 divisions (Figure 9, Table 3). The vegetation of each group will be described using species which have either a frequency greater that 50% or a Domin score of 4-10 in at least 20% of the quadrats.

The first TWINSPAN division separated a group of 59 quadrats (Group H) from the remaining 474. This group contained 55 of the 90 quadrats from the OG treatments, and the group was characterized by orchard grass.

The second division created two macrogroups, one branch which led to groups A and B, the other to groups C-G. Groups A and B, consisting of 33 and 55 quadrats respectively, were finalized at the third division level. These were primarily from Site B (excluding RF-B). Both groups were characterized by wild carrot, daisy, and St. John's wort. In addition, group A was characterized by horsetail, coltsfoot, cedar, Canada goldenrod, bracken and tall goldenrod, while group B contained strawberry, Canada bluegrass and heart-leaved aster.

Figure 3: The importance value curves of the species in plot A

(see methods for an explanation of this plot, and the appendix for a listing ofthe species codes)

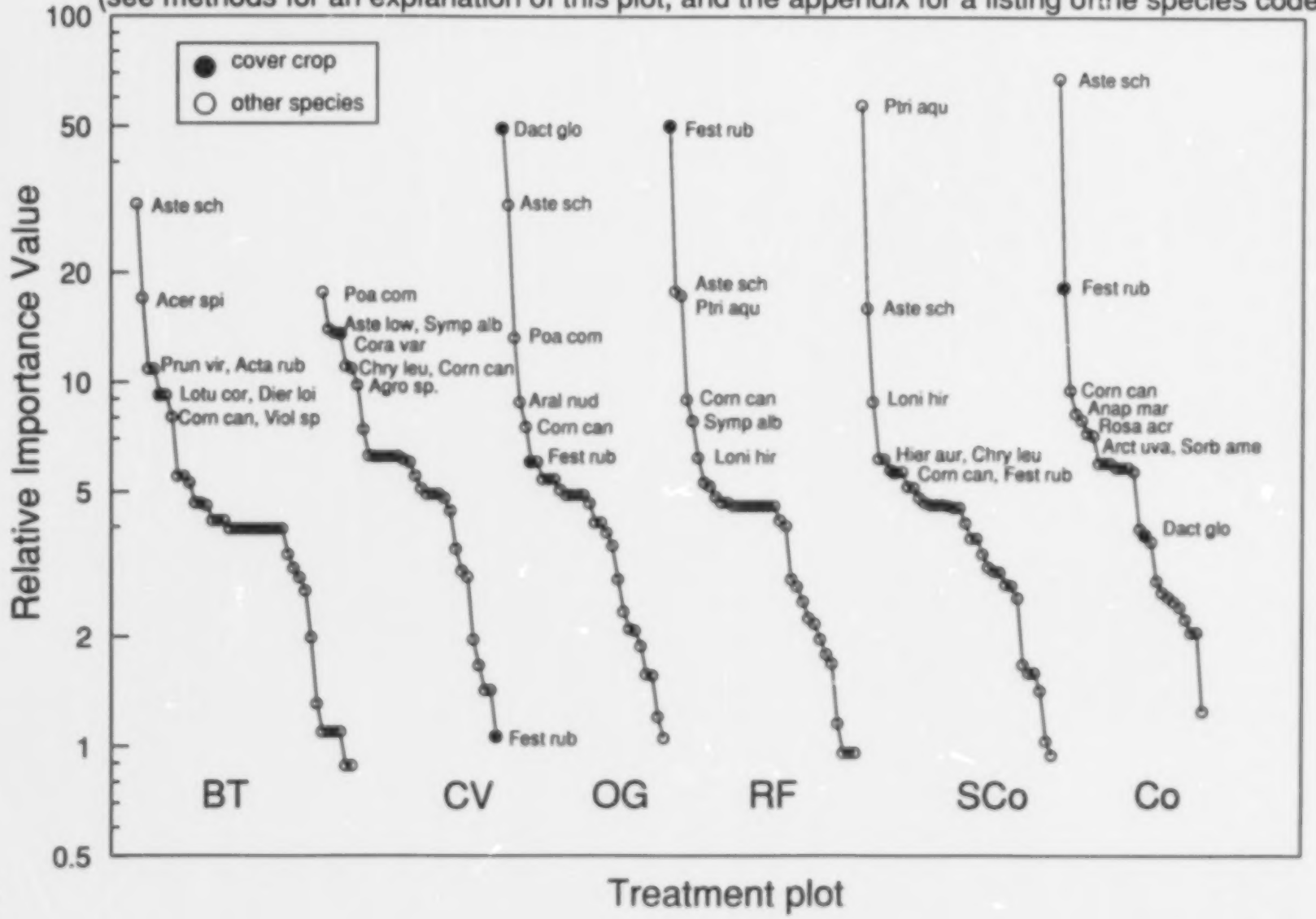


Figure 4: The importance value curves of the species in plot B

(see methods for an explanation of this plot, and the appendix for a listing ofthe species codes)

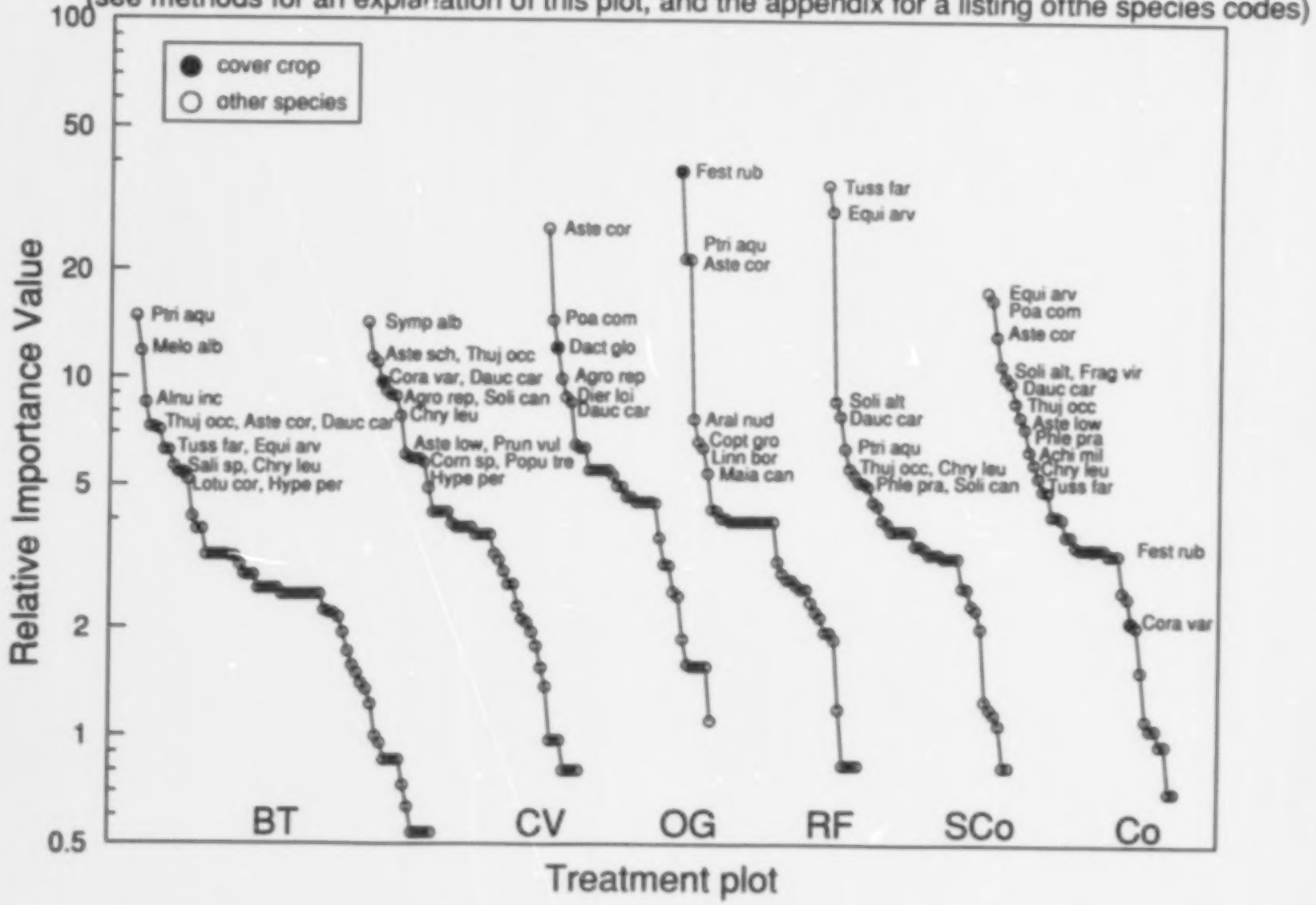


Figure 5: The importance value curves of the species in plot C

(see methods for an explanation of this plot, and the appendix for a listing ofthe species codes)

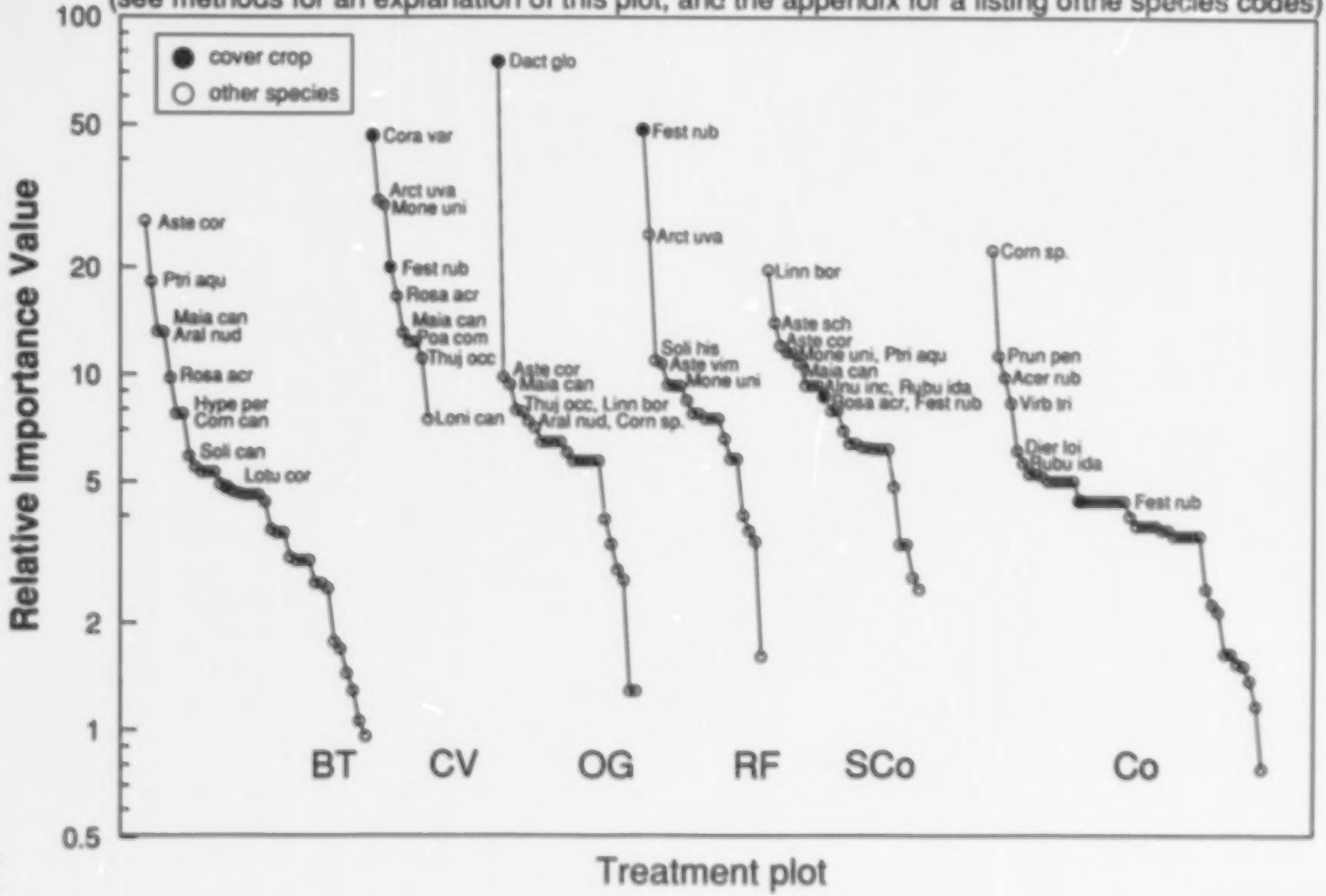


Figure 6: The importance value curves of the species in plot D
(see methods for an explanation of this plot, and the appendix for a listing ofthe species codes)

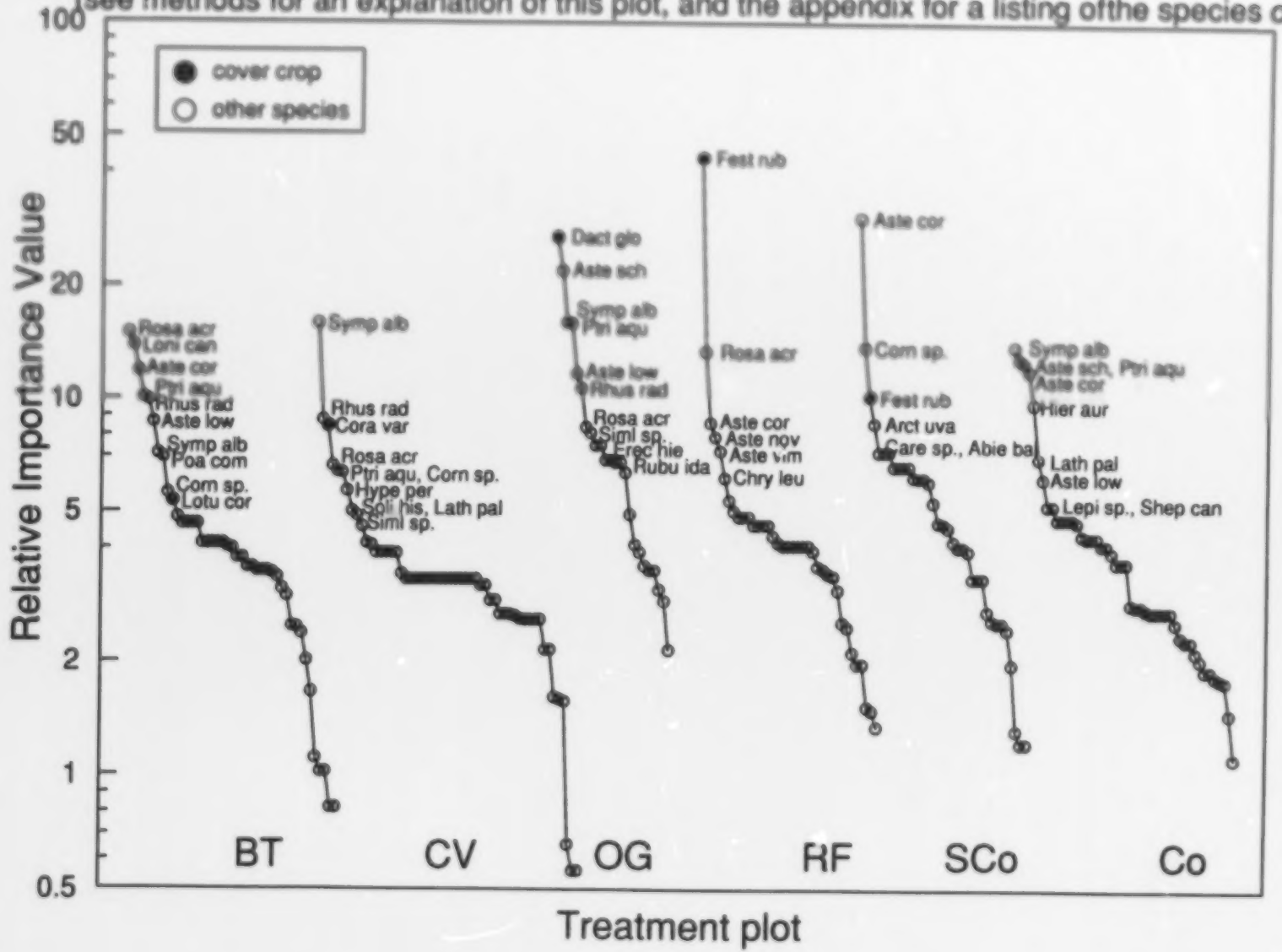


Figure 7: The importance value curves of the species in plot E
(see methods for an explanation of this plot, and the appendix for a listing ofthe species codes)

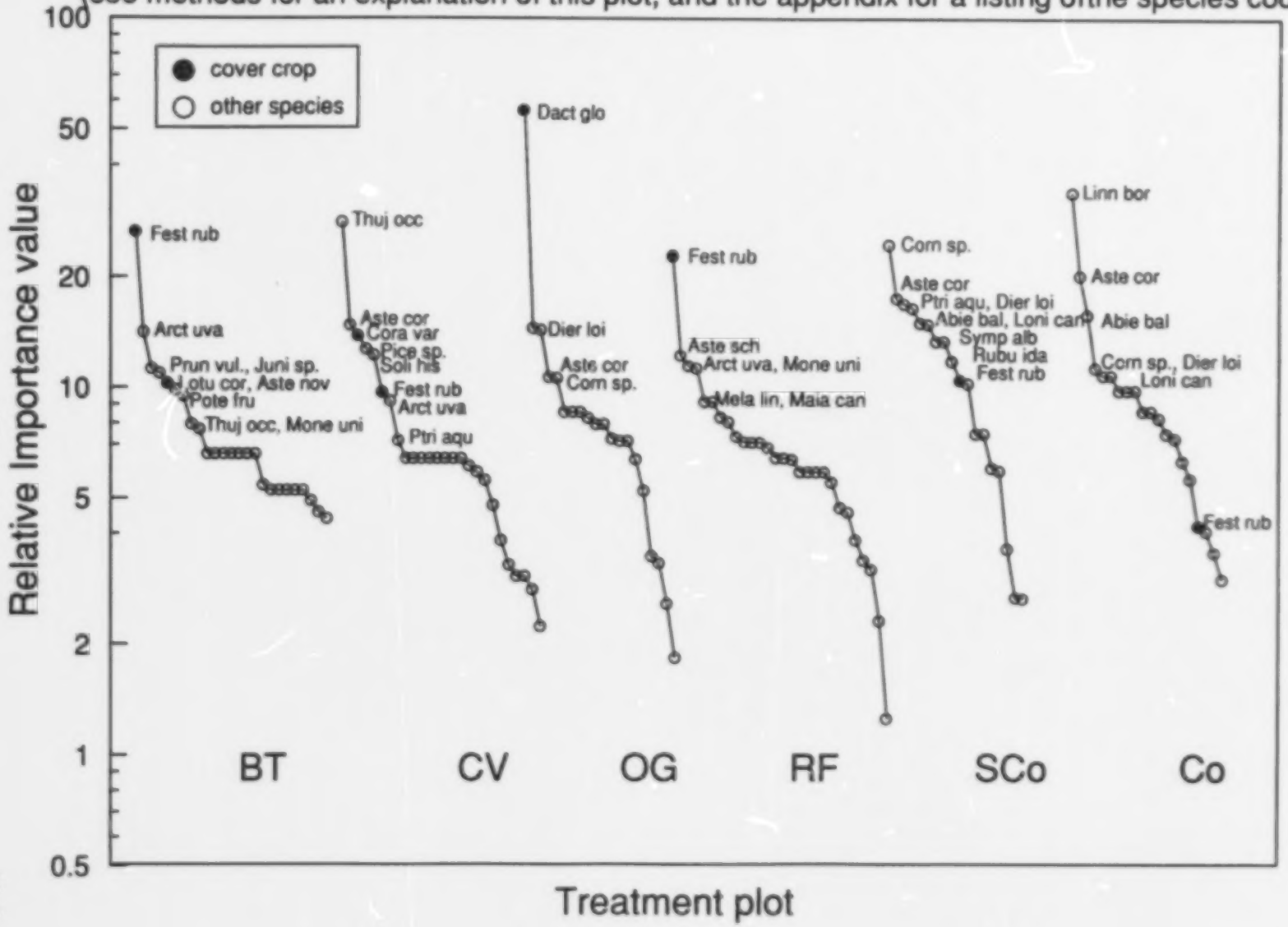


Figure 8: The importance value curve of the species in plot F

(see methods for an explanation of this plot, and the appendix for a listing ofthe species codes)

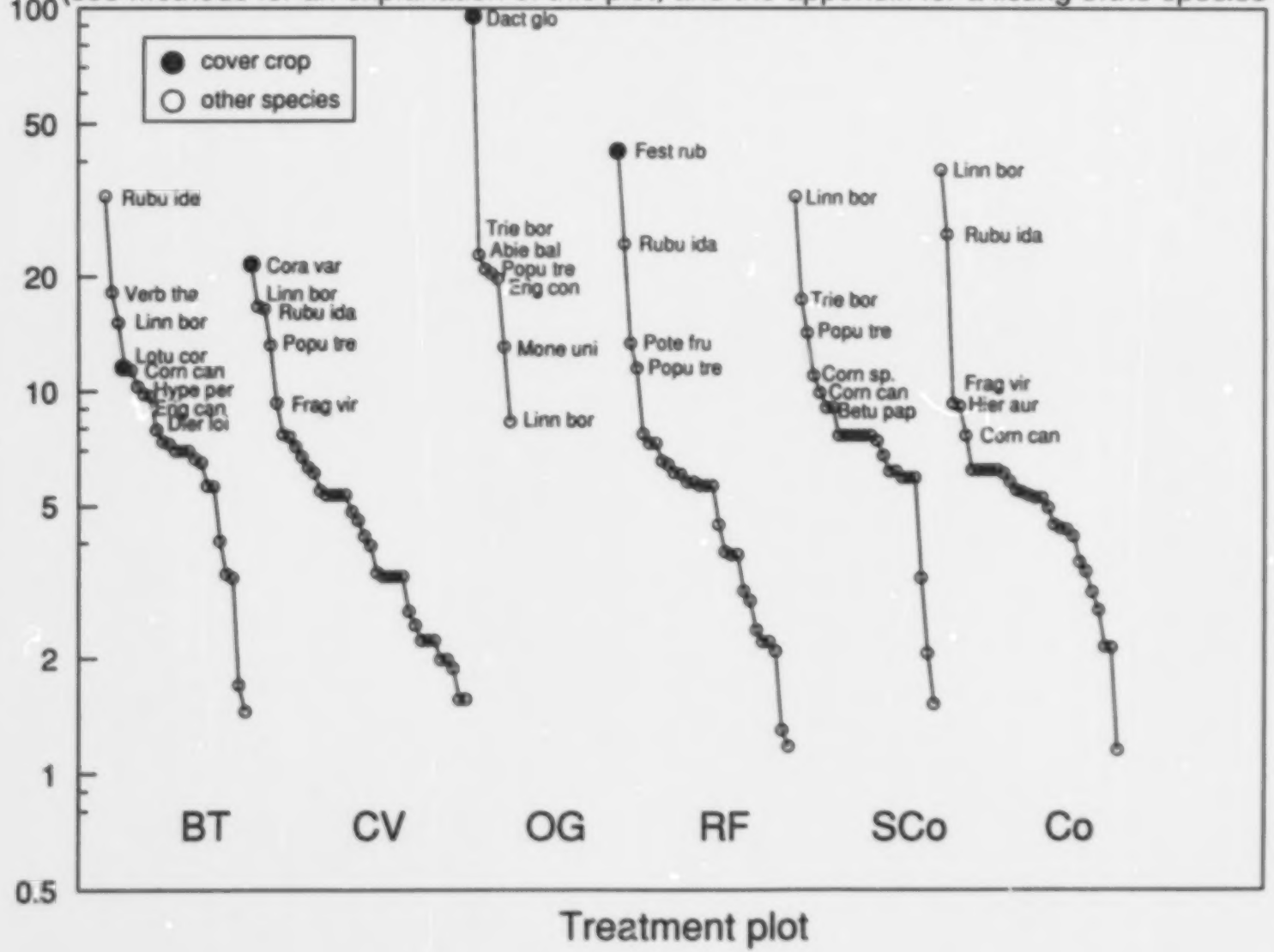


Figure 9: The TWINSPAN groupings of the quadrats, with the indicator species for each division

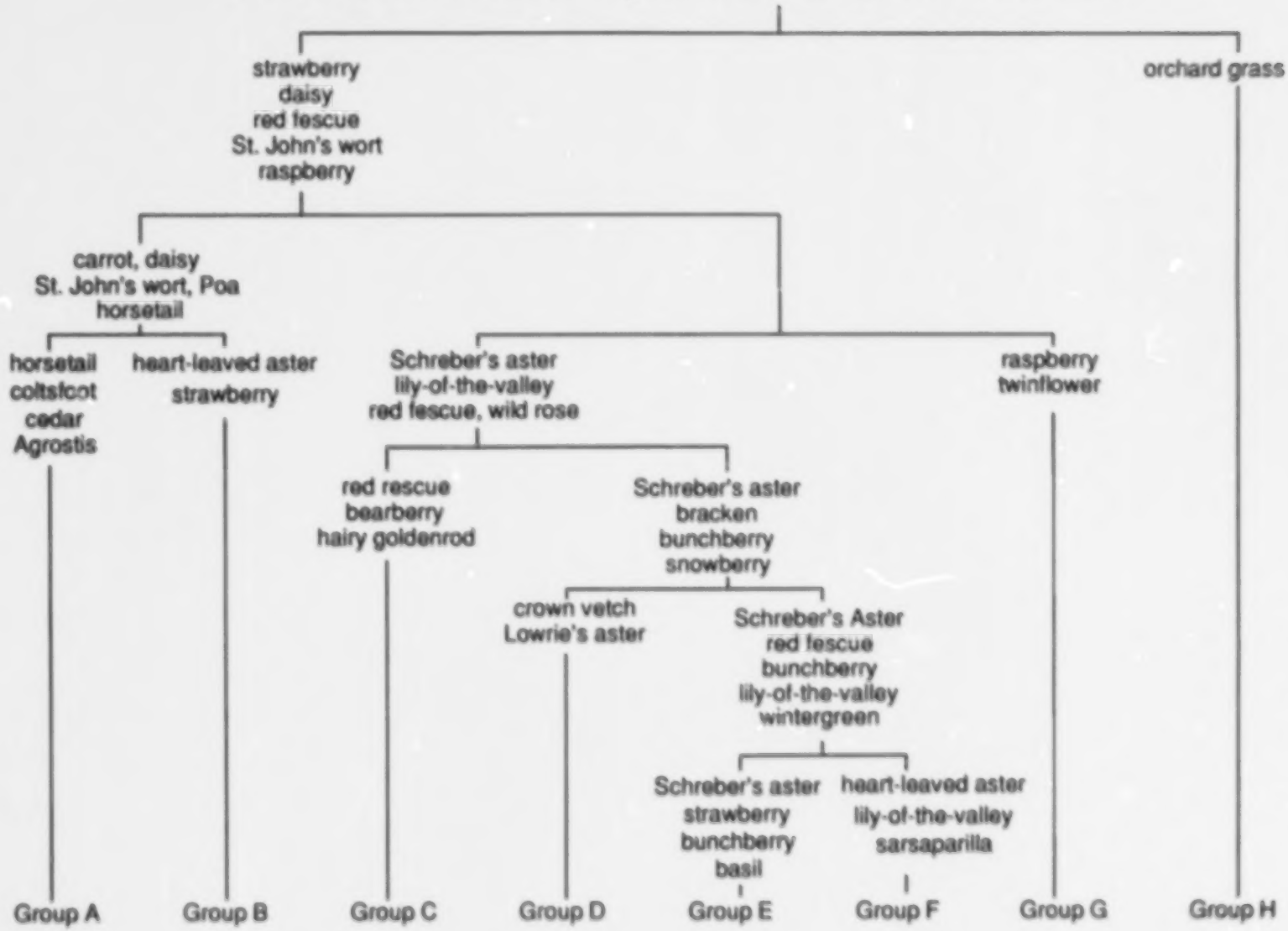


Table 3

Distribution of quadrats in 8 TWINSPAN Groups

Group A		Group B		Group C		Group D	
a	b	a	b	a	b	a	b
BT-A	1	CV-A	3	BT-A	1	Co-A	1
CV-B	1	CV-B	6	RF-A	3	CV-A	6
Co-B	2	OG-B	8	CV-C	3	CV-B	5
SCo-B	15	Co-B	13	RF-C	14	OG-B	1
BT-B	8	BT-B	6	SCo-C	1	CV-C	5
RF-B	2	SCo-C	1	Co-C	1	Co-C	6
CV-C	1	BT-C	3	RF-D	12	SCo-D	6
SCo-C	1	Co-C	1	SCo-D	5	BT-D	8
Co-C	1	RF-D	1	BT-D	1	CV-D	10
RF-D	1	SCo-D	2	CV-D	2	Co-D	6
		BT-D	3	OG-D	1	OG-D	5
		CV-D	1	BT-E	13	CV-E	4
		SCo-E	1	RF-E	10	Co-E	3
		Co-F	1	CV-E	9	SCo-E	2
		RF-F	1	Co-E	2	OG-E	2
		SCo-F	1	RF-F	6	RF-F	1
		CV-F	3	CV-F	2		

Group E		Group F		Group G		Group H	
a	b	a	b	a	b	a	b
BT-A	11	BT-A	1	BT-A	1	OG-A	7
OG-A	7	SCo-A	1	OG-A	1	OG-B	2
Co-A	14	RF-A	1	CV-A	3	OG-C	15
CV-A	3	OG-B	2	SCo-A	2	OG-D	6
SCo-A	12	BT-B	1	CV-B	1	OG-E	10
RF-A	11	RF-B	13	OG-B	1	OG-F	15
CV-B	2	CV-C	4	CV-C	1	RF-C	1
OG-B	1	SCo-C	5	SCo-C	2	SCo-C	1
SCo-C	2	BT-C	12	Co-C	4	Co-E	1
Co-C	2	RF-D	1	Co-D	1	SCo-F	1
BT-D	1	SCo-D	2	RF-E	1		
Co-D	7	BT-D	2	CV-E	1		
OG-D	3	CV-D	2	Co-E	7		
BT-E	1	Co-D	1	SCo-E	7		
RF-E	1	BT-E	1	OG-E	2		
SCo-E	1	RF-E	3	Co-F	13		
		CV-E	1	RF-F	7		
		Co-E	1	SCo-F	13		
		SCo-E	2	BT-F	15		
		OG-E	1	CV-F	10		

a plot
b number of quadrats

Group G was also formed at the third division level. This group contained 93 quadrats characterized by raspberry, twinflower and bunchberry. It consisted of a large number of quadrats from the BT, CV, SCo and Co treatments at site F.

The fourth division level produced Group C, containing 64 quadrats from RF-C, RF-D, RF-E, RF-F, BT-E and CV-E, plus an additional 22 quadrats. It was dominated by red fescue, bearberry, cedar and hairy goldenrod.

Group D did not have any species with a frequency above 50%, although crown vetch and snowberry were present in 40 % of the quadrats. Snowberry, Lowrie's aster, heart-leaved aster, dogwood and wild rose had high covers. 35 of the 71 quadrats in this group were from site D, and 30 of the quadrats contained crown vetch.

The sixth TWINSPAN division separated Group E (79 quadrats) from Group F (57 quadrats). Group E was characterized by Schreber's aster, bunchberry, bracken and red fescue and had high representation from site A (BT-A, RF-A, SCo-A, Co-A). Group F had high representation from RF-B and BT-C, and was characterized by lily-of-the-valley, heart-leaved aster, bracken, red fescue, sarsaparilla and wild rose.

In the ANOVA of the species richness data (Table 2), site had a high F value and the TWINSPAN divisions were dominated by single sites (Groups A, B, E, F, G). This suggests that the vegetation was more influenced by site than by treatment. However, many of the OG and RF treatments were grouped into distinct communities (Group H, C), and it is encouraging to see 36% of the quadrats which contained crown vetch falling into a single group (Group D). This allows speculation that as the crops become better established their effect may increase in importance.

3.3 The Incompatible Trees

There has been little change in the density of incompatible trees between 1989 (0.921 stems$\cdot m^{-2}$, Brown 1990a) and 1990 (1.057 stems$\cdot m^{-2}$). Similar to last year, the ANOVA indicates that tree density was not affected by treatment but was strongly affected by site (Table 4). Sites E and F have a significantly higher density (Figure 10).

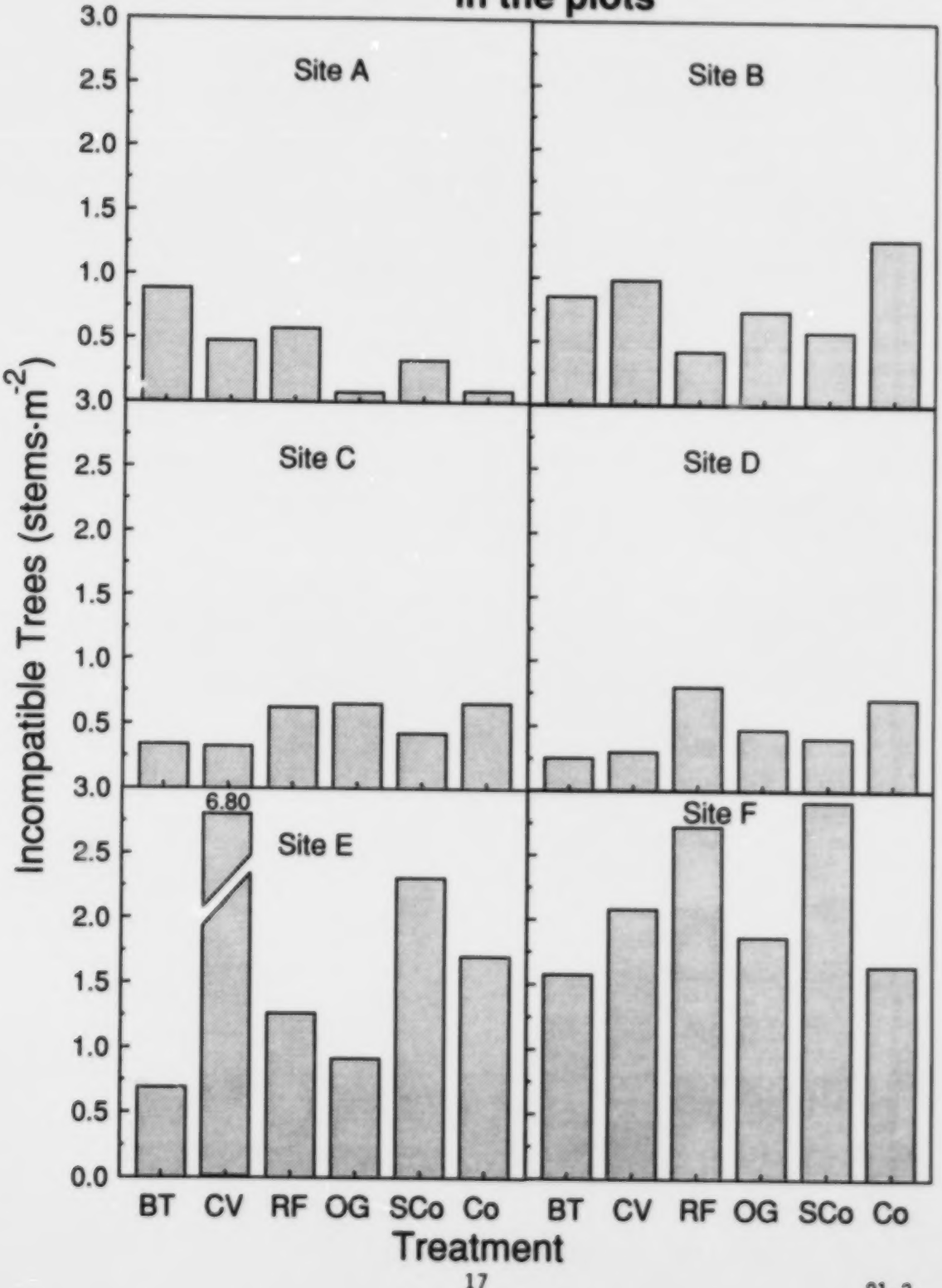
Table 4

The ANOVA of the variation in tree density between sites and cover crop treatments.

Source	SS	DF	MS	F-ratio	*p*
MAIN EFFECTS	19.3479	10	1.9348	4.849	0.0007
plot	18.2844	5	3.6569	9.159	>0.000
treatment	1.0635	5	0.2127	0.533	0.7494
RESIDUAL	9.9820	25	0.3993		
TOTAL (corr.)	29.3299	35			

The contingency table analysis indicated that, of the 25 species occurring in at least 50 quadrats, orchard grass and 5 other species (basil, bracken, wild rose, lily-of-the-valley, Schreber's aster) had negative associations with any tree and 2 species (twinflower, snowberry) had positive associations (Table 5). The quadrats which contained orchard grass had a lower than expected tree frequency (10%, relative to a frequency of 25% for all trees), thus there does appear to be a differential cover crop effect.

Figure 10: The density of incompatible trees in the plots



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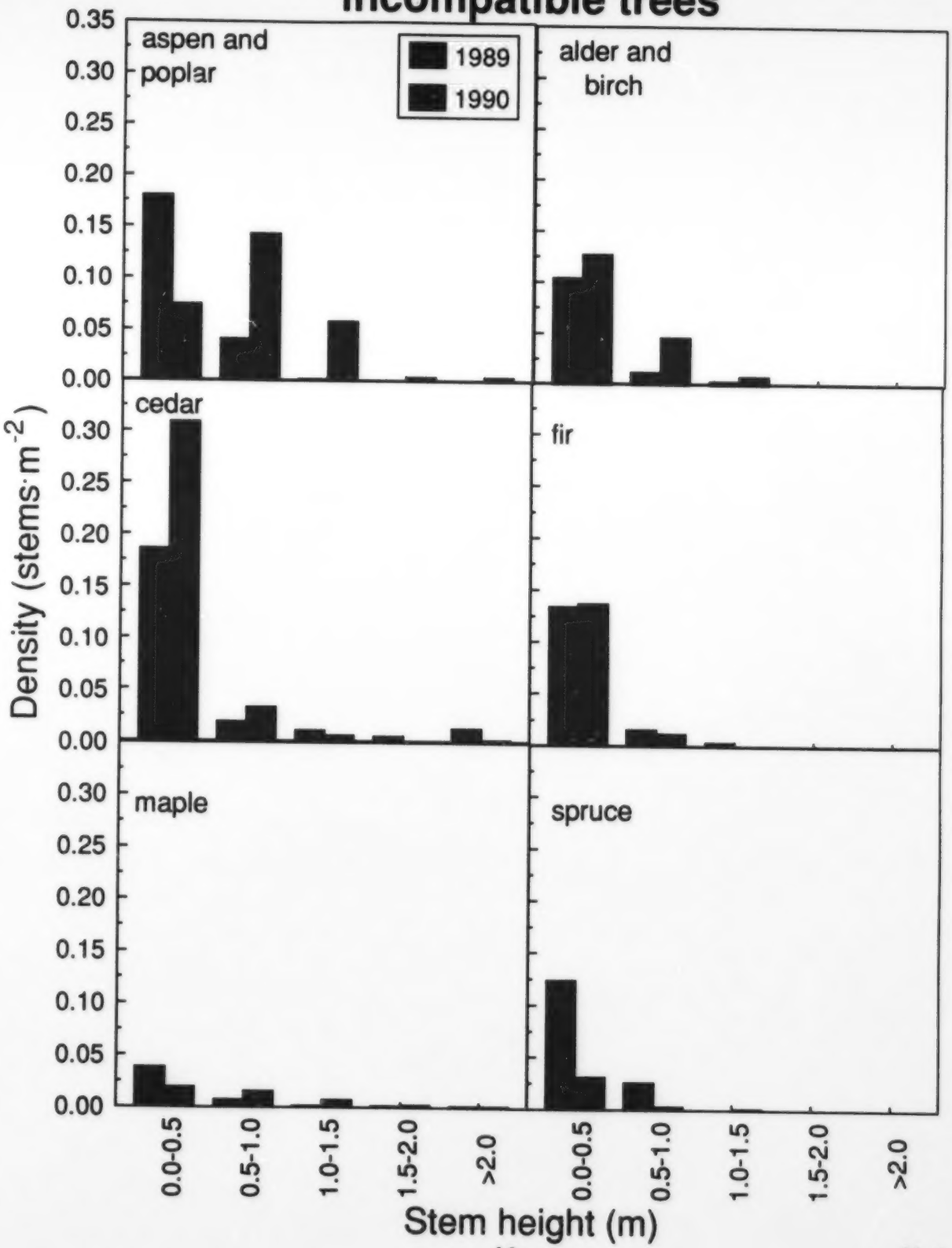
A comparison of the sizes of the major trees groups between 1989 and 1990 is presented in Figure 11. Although there was no overall change in tree density, there appear to be some shifts in the species present and their size. There was a large increase in the density of small cedars (<0.5 m tall), from 0.186 stems$\cdot m^{-2}$ in 1989 to 0.309 stems$\cdot m^{-2}$ in 1990. Many of the cedars were located in barren, rocky habitats in plots Co-B, SCo-B and CV-E, and will probably not grow to a size which will create a treatment problem. The total number of spruce and birch have declined, while alder has increased. The density of aspen and poplar has remained relatively constant, however, these trees have grown considerably. The size distribution indicated many more individuals in the 0.5-1.0 and 1.0-1.5 m height classes. They represent a major control problem at site F, where densities range from 0.95 to 2.5 stems$\cdot m^{-2}$, and in the CV, OG and BT treatments at site B.

Table 5

Contingency table analysis showing the association between the more abundant species and all incompatible trees.

Species	Occurrences	Chi-square	*p*	Association
snowberry	64	248.0	>0.00	positive
orchard grass	77	7.64	0.005	negative
bracken	81	7.18	0.007	negative
wild rose	75	7.08	0.008	negative
lily-of-the-valley	112	5.57	0.018	negative
Schreber's aster	127	5.53	0.018	negative
basil	74	5.33	0.02	negative
twinflower	101	4.66	0.031	positive
sarsaparilla	60	2.25	0.14	
Canada bluegrass	105	2.21	0.13	
raspberry	84	2.03	0.15	
wild carrot	93	1.84	0.17	
red fescue	133	1.39	0.24	
birdsfoot trefoil	64	1.21	0.27	
bunchberry	102	1.13	0.28	
starflower	54	0.92	0.34	
Lowerie's aster	90	0.85	0.35	
crown vetch	84	0.73	0.39	
self heal	53	0.49	0.48	
daisy	147	0.42	0.52	
wintergreen	92	0.367	0.54	
strawberry	148	0.016	0.89	
St. John's wort	135	0.014	0.90	
dandelion	52	0.007	0.92	
heart-leaved aster	123	0.002	0.95	

Figure 11: The height distrubution of the incompatible trees



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4.0 DISCUSSION

There are several questions which need to be answered for an evaluation of a cover crop program designed to control tree growth. Can you establish a cover crop on the right-of-way? Is that well established cover crop inhibiting tree growth better than the native groundcovers? How long can the cover crop persist in light of competition from the native vegetation? When reasonable answers are obtained for these questions, then a decision on the feasibility and economics of the cover crop approach can be made.

The answer to the question of cover crop establishment is affected by the scale of sampling. In many quadrats red fescue and orchard grass achieved a domin rating of 9 (75-95% cover) indicating excellent establishment. However, when the quadrats are averaged to produce the plot value, the highest cover of these grasses in any plot was 50%, while the mean of all 6 plots was 25% (Figure 1). In the association analysis of the quadrats, orchard grass was negatively associated with any tree (Table 5), yet the OG treatment did not reduce the tree density at the plot level (Table 4, Figure 10). This suggests that the crop can achieve a desirable cover, but patchiness allows ample room for invasion by incompatible trees at the plot scale. This heterogeneity of the environment serves to maintain species diversity and prevent competitive exclusion (DeAngelis and Waterhouse 1987, Grime *et al.* 1987, Tilman 1989, Epp and Aarssen 1989).

The vegetation is probably still responding to the disruption caused by the scarification and seeding. The presence of the cover crops have increased dramatically in 1990 (Figure 1), and they are having a significant role in the ecology at both the plot and quadrat levels. This is evident in the dominance of crown vetch, red fescue and orchard grass in the importance value curves for the treatment plots (Figure 3-8) and in the prominence of red fescue and orchard grass in the TWINSPAN classification (Figure 9). Birdsfoot trefoil is the only crop for which there in no evidence for an influential role.

There is some similarity between the species composition of the plots as indicated by the importance value (IV) curves and the classification groups of the quadrats. The major species in TWINSPAN Groups A and B were similar to the species with high IV in BT-B, CV-B, SCo-B and Co-B. Similarly, Group D was dominated by species with high IV in BT-D, CV-D, OG-D and CO-D, Group E was dominated by species with large IV in BT-A, OG-A, RF-A, SCo-A and Co-A, and Group G was dominated by species with large IV in BT-F, CV-F, SCo-F and Co-F. This is evidence indicating that there were more differences in the vegetation between sites than between treatments within a site. The fact that most quadrats from OG-A, OG-B, OG-D, OG-F, RF-B, RF-C, RF-D and RF-F did not associate with these groups, but formed their own groups dominated by orchard grass (Group H) or red fescue (Groups C, F), is strong evidence that the orchard grass and red fescue were affecting the vegetation in those treatment plots.

The OG treatment also had the lowest species richness (Figure 2), which is also suggestive of the dominant role of the cover crop in these plots.

Although the RF and OG treatments had an influence on the vegetation, they did not affect the tree density (Table 4, Figure 10). Many of these trees were established in or prior to 1989 (Figure 11), before any of the cover crops achieved a significant cover (Figure 1). With the exception of cedar, there was no net change in the density of seedling sized stems in 1990, suggesting that once the vegetation achieved a significant cover it was able to exert some control over tree establishment.

A similar invasion pattern was observed at McCowan Road study site (Brown 1989c), where there was a rapid colonization by tree seedlings and sprouts in the first year post cutting, while stem densities declined in subsequent years. This indicates that a critical time for tree invasion is the first growing season following clearing of the new right-of-way. This is a time in which sprouting is maximal (Brown 1989c), damage to the native vegetation resulting from construction has left many bare patches for tree seedlings to establish, and the cover crops have not developed to any significant degree (Figure 1).

It remains to be seen whether the improved growth of the cover crops will provide adequate interference to reduce the growth of these established trees in future years. The aspen at sites B and F have grown rapidly during the past year (Figure 11), and will most likely be the first trees which will require clearing. No cover crop will prevent tree growth entirely, so that developing effective methods for tree removal, which limits sprouting and prevents damage to the cover crop, will be necessary.

A well established cover crop has been show to inhibit the growth of trees from seeds, transplants and cuttings under controlled conditions (Brown 1990b), while several field studies have indicated the crops used in this project have a large potential to control unwanted trees:

A grass mixture which included red fescue reduced the density and height of trembling aspen suckers (Bailey 1972). The Tennessee Valley Authority uses red fescue as a cover on their rights-of-ways, and in combination with regular mowing has achieved desirable vegetation control (Allsbrooks *et al.* 1984). Stott (1976) found a mixture of red fescue and Kentucky blue grass was more inhibitory to apple growth that a mix of clover and blue grass. An English study suggested that red fescue was no better than native grasses in the control of birch, although it was found to be a very persistent grass (Buckley 1984).

Orchard grass has inhibited the growth of apple in field and greenhouse trials (Shribbs *et al.* 1986, Shribbs and Shroch 1986). It was more inhibitory than native grasses on ponderosa pine (Elliot and White 1987). Cover crop mixtures including orchard grass were also effective at reducing growth in apple and Douglas-fir (Rogers *et al* 1948, Eissenstat and Mitchell 1983). A study in British Columbia indicated that orchard grass provided better control when compared with the scarified - unseeded plots, but was no more effective than either red fescue, timothy or brome grass (Clark and McLean 1979).

Studies using birdsfoot trefoil or crown vetch are less numerous. Sharp *et al.* (1980) found a negative correlation between crown vetch and tree densities on highway rights-of-way, while Osmars (1975) recommended crown vetch to Ontario Hydro for additional testing. Birdsfoot trefoil reduced the growth of hybrid poplar for 3 years post seeding, although the trefoil was rapidly invaded by weeds and its cover did not exceed 20% after the first year (McLaughlin *et al.* 1985).

These studies suggest that a cover crop approach will affect the growth and density of tree seedlings and sprouts on the rights-of-way, although this has yet to be confirmed by this project. Aspects which need to be clarified are: Under what conditions will a cover crop perform significantly better than the native vegetation? Which is the best crop species or mixture for those conditions? Can the crop be established on the heterogeneous right-of-way such that there is a minimum of areas suitable for tree establishment? How should the crop be managed to ensure long term effectiveness?

5.0 CONCLUSIONS

1. The cover crops have increased in 1990. Red fescue and orchard grass are the dominant species in their respective plots. Crown vetch and birdsfoot trefoil were present at high frequencies, but consisted of small plants with low cover.

2. The total density of incompatible trees (1.057 stems m^{-2}) has not changed. The distribution of trees varied significantly between sites, but was not affected by the treatments. Orchard grass was negatively associated with trees at the scale of the quadrat.

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APPENDIX A: A LIST OF SPECIES FOUND AT TOBERMORY IN 1990.

Species Name	Common Name	Code
Abies balsamea	balsam fir	Able bal
Acer spicatum	mountain maple	Acer spi
Acer rubrum	red maple	Acer rub
Achillea millefolium	yarrow	Achi mil
Actaea rubra	red baneberry	Acta rub
Agropyron repens	couch grass/quack grass	Agro rep
Agrostis perennans	upland bentgrass	Agro per
Agrostis sp	bentgrass	Agro sp
Agrostis hyemalis	tickegrass	Agro hye
Agrostis alba	red top bentgrass	Agro alb
Alnus incana	speckled alder	Alnu inc
Amelanchier stolonifera	serviceberry	Amel sto
Anaphalis margaritacea	pearly everlasting	Anap mar
Apocynum androsaemifolium	dogbane	Apoc and
Aquilegia canadensis	columbine	Aqui can
Aralia nudicaulis	Sarsaparilla	Aral nud
Arctostaphylos uva-ursi	bearberry	Arct uva
Arenaria lateriflora	sandwort	Aren lat
Artemisia caudata	tall wormwood	Arte cau
Aster novae-angliae	New England aster	Aste nov
Aster macrophyllus	large leaved aster	Aste mac
Aster schreberi	Schrebber's aster	Aste sch
Aster lowrieanus	Lowrie's aster	Aste low
Aster cordifolius	heart leaved aster	Aste cor
Aster vimineus	small white aster	Aste vim
Aster tradescanti	tradescant's aster	Aste tra
Athyrium filix-femina	lady fern	Athy fil
Betula papyrifera	white birch	Betu pap
Campanula rotundifolia	blue bell	Camp rot
Carex sylvatica	wood sedge	Care syl
Carex sp	Sedge	Care sp
Carex flava		Care fla
Cerastium vulgatum	mouse eared chickweed	Cera vul
Chrysanthemum leucanthemum	daisy	Chry leu
Cirsium vulgare	bull thistle	Cirs vul
Cirsium sp	thistle	Cirs sp
Cirsium arvense	Canada thistle	Cirs arv
Cirsium discolour	field thistle	Cirs dis
Clintonia borealis	bluebeard	Clin bor
Comandra umbellata	bastard toadflax	Coma umb
Coptis groenlandica	goldthread	Copt gro

APPENDIX A: A LIST OF SPECIES FOUND AT TOBERMORY IN 1990. (cont'd)

Species Name	Common Name	Code
Cornus sp	dogwood	Corn sp
Cornus canadensis	bunchberry	Corn can
Cornus stolonifera	red osier dogwood	Corn sto
Coronilla varia	crown vetch	Coro var
Cypripedium sp	lady's slipper	Cypr sp
Dactylis glomerata	orchard grass	Dact glo
Daucus carota	wild carrot	Dauc car
Diervilla lonicera	bush honeysuckle	Dier lon
Epipactis helleborine	helleborine	Epip hel
Equisetum sp	horsetail	Equi sp
Equisetum arvense	field horsetail	Equi arv
Erechtites hieracifolia	pilewort	Erec hie
Erigeron canadensis	horseweed	Erig can
Festuca elatior	meadow fescue	Fest ela
Festuca rubra	red fescue	Fest rub
Fragaria virginiana	strawberry	Frag vir
Fraxinus pennsylvanica	green ash	Frax pen
Galium triflorum	fragrant bedstraw	Gali tri
Geranium robertianum	herb robert	Gera rob
Geranium maculatum	wild geranium	Gera mac
Hieracium aurantiacum	orange hawkweed	Hier aur
Houstonia canadensis	fringed houstonia	Hous can
Hypericum perforatum	common St. John's wort	Hype per
Juniperus sp	juniper	Juni sp
Lactuca scariola	prickly lettuce	Lact sca
Lactuca hirsuta	hairy lettuce	Lact hir
Lactuca canadensis	wild lettuce	Lact can
Lathyrus palustris	marsh vetchling	Lath pal
Lepidium campestre	field peppergrass	Lepi cam
Lepidium virginicum	peppergrass	Lepi vir
Lilium philadelphicum	wood lily	Lil phi
Linnaea borealis	twinflower	Linn bor
Lolium perenne	perennial rye	Loli per
Lonicera hirsuta	hairy honeysuckle	Loni hir
Lonicera dioica	glaucous honeysuckle	Loni dio
Lonicera canadensis	fly honeysuckle	Loni can
Lotus corniculatus	birdsfoot trefoil	Lotu cor
Lycopus americanus	water horehound	Lyco ame
Maianthemum canadense	wild lily-of-the-valley	Maia can
Medicago lupulina	black medick	Medi lup
Melampyrum lineare	cow wheat	Mela lin
Melanthium virginicum	bunch flower	Mela vir
Melilotus alba	white sweet clover	Meli alb
Moneses uniflora	wintergreen	Mone uni

APPENDIX A: A LIST OF SPECIES FOUND AT TOBERMORY IN 1990. (cont'd)

Species Name	Common Name	Code
Onopordum acanthium	scotch thistle	Onop aca
Oxalis corniculata	creeping wood sorrel	Oxal cor
Panicum sp		Pani sp
Panicum clandestinum	deer tongue grass	Pani cla
Parnassia glauca	Grass of Parnassus	Parn gla
Phleum pratense	timothy	Phle pra
Picea sp	spruce	Pice sp
Plantago lanceolata	grass leaved plantain	Plan lan
Plantago major	common plantain	Plan maj
Poa compressa	Canada bluegrass	Poa com
Populus tremuloides	trembling aspen	Popu tre
Potentilla fruticosa	shrubby cinquefoil	Pote fru
Potentilla anserina	silverweed	Pote ans
Primula mistassinica	bird's eye primrose	Prim mis
Prunella vulgaris	heal all/self heal	Prun vul
Prunus pensylvanica	pin cherry	Prun pen
Prunus virginiana	choke cherry	Prun vir
Pteridium aquilinum	bracken fern	Pter aqu
Pyrola elliptica	shinleaf	Pyro ell
Ranunculus acris	buttercup	Ranu acr
Rhus radicans	poison ivy	Rhus rad
Ribes triste	swamp red currant	Ribe tri
Ribes lacustre	bristly blackcurrent	Ribe lac
Rosa acicularis	prickly wild rose	Rosa aci
Rubus pubescens	dwarf raspberry	Rubu pub
Rubus idaeus	common raspberry	Rubu ida
Salix sp	willow	Sali sp
Satureja vulgaris	basil	Satu vul
Scutellaria parvula	small skullcap	Scut par
Secale cereale	rye	Seca cer
Shepherdia canadensis	soapberry	Shep can
Silene cucubalus	bladder campion	Sile cuc
Silene noctiflora	night flowering catchfly	Sile noc
Smilacina racemosa	false solomon's seal	Smil rac
Smilacina stellata	star solomon's seal	Smil ste
Solanum dulcamara	bittersweet nightshade	Sola dul
Solidago speciosa	showy goldenrod	Soli spe
Solidago altissima	tall goldenrod	Soli alt
Solidago canadensis	Canada goldenrod	Soli can
Solidago juncea	early goldenrod	Soli jun
Solidago odora	sweet goldenrod	Soli odo
Solidago hispida	hairy goldenrod	Soli his

APPENDIX A: A LIST OF SPECIES FOUND AT TOBERMORY IN 1990. (cont'd)

Species Name	Common Name	Code
Sonchus sp	sow thistle	Sonc sp
Sonchus oleraceus	common sow thistle	Sonc ole
Sorbus americana	mountain ash	Sorb ame
Symphoricarpos albus	snowberry	Symp alb
Tanacetum vulgare	Tansy	Tana vul
Taraxacum officinale	common dandelion	Tara off
Thalictrum polygamum	tall meadow rue	Thal pol
Thuja occidentalis	white cedar	Thuj occ
Tiarella cordifolia	foamflower	Tiar cor
TOB90A	Unknown A	TOB90A
TOB90B	unknown B	TOB90B
TOB90C	unknown C	TOB90C
TOB90D	Unknown D	TOB90D
TOB90E	unknown E	TOB90E
Tragopogon pratensis	yellow goatsbeard	Trag pra
Trientalis borealis	starflower	Trie bor
Trifolium pratense	red clover	Trif pra
Tussilago farfara	coltsfoot	Tuss far
Unknown Mustard		mustard
Verbascum thapsus	mullen	Verb tha
Viburnum trilobum	highbush cranberry	Vibu tri
Viola sp	violet	Viol sp
Waldsteinia fragarioides	barren strawberry	Wald fra